estimate

estimate • analyze • plan • control

QuickCost 6.0

Introduction and Overview

Dr. Joseph Hamaker & Ronald Larson

Galorath Federal

SEER® GALORATH

NASA Cost Symposium 2015 Ames Research Center 25-27 August 2015

Background

- QuickCost is a top level parametric cost model
- Initially developed beginning in 2001 (by Hamaker) while with the CAD at NASA HQ
- Updated and evolved while with SAIC and TMGI up through Version 5.0
- Version 6.0 is a update to be completed by December 31, 2015 (midnight)

	QuickCost 1.0	QuickCost 2.0	QuickCost 3.0	QuickCost 4.0	QuickCost 5.0
	Dissertation Proposal	Dissertation In Work	Dissertation Final	CAD Funded 2009	CAD Funded 2010
Release date	October 1, 2004	December 1, 2005	February 1, 2006	September 1, 2009	January 31, 2011
R^2 adjusted	82.8%	77.0%	86.0%	88.4%	86.1%
Number data points	122	131	120	120	132
Total Mass	x	x	x	x	x
Power	x	x		x	x
Design life	x	x		x	x
Year tech/ATP date	x	x		x	x
Reqmts stability/volatility	x				
Funding stability	x				
Test	x				
Number instruments	x				
Pre-development study	x				
Team	x			x	
Apogee		x			
Percent new		x		x	
Bus new					x
Instrument new					x
Planetary/Destination			x	x	x
ECMPLX			x		
MCMPLX			x		
Data rate%				x	
Instrument complexity%				x	x

QuickCost Architecture

- QuickCost is Microsoft Excel-based tool consisting of nine worksheets:

Worksheet Tab	Worksheet Content
Satellite DB	Historical database
Satellite Model	Main satellite cost model
Satellite Trades Model	Expanded capability model
Module & Transfer Vehicle DB	Historical database
Module & Transfer Vehicle Model	Module and TV model
X Vehicle DB	Historical database
X Vehicle Model	X Vehicle Model
Liquid Rocket Engine DB	Historical database
Liquid Rocket Engine Model	LRE Model

Currently only these two worksheets being updated

QuickCost Intended Use

- QuickCost, throughout its history, has been meant to be used to estimate the cost and schedule (i.e. total Phase B-D span) of NASA missions at…
  - Pre-Phase A
  - Phase A
  - Maybe Phase B (for the truly desperate)

- Another notion that QuickCost stubbornly adheres to is the idea that accurate cost and schedule estimating can be done at the top levels of the WBS
  - One does not need to count the trees to estimate the forest
  - In fact, details can be quite detrimental to good estimating
    - But that's another talk*

*"Is It Necessary To Count The Trees To Estimate The Forest?"
Joe Hamaker, NASA 2009 Cost Analysis Symposium
Kennedy Space Center
April 28-30, 2009

The Major New Distinguishing Feature of QuickCost 6.0

- For the Satellite database, QuickCost 5.0 included 132 data points (going back to missions launched in the early 1960s)
  - Obviously a lot of pre-CADRe data
  - Data from a wide range of sources
    - Including some Hamaker may have made up

- QuickCost 6.0 will use only CADRe data and only missions for which either a Launch or End-of-Mission CADRe exists as well as missions for which a CADRe+ has been developed
  - Ends up being 72 data points
  - Hopefully more accurately portrays today's NASA
  - Still provides plenty of degrees of freedom

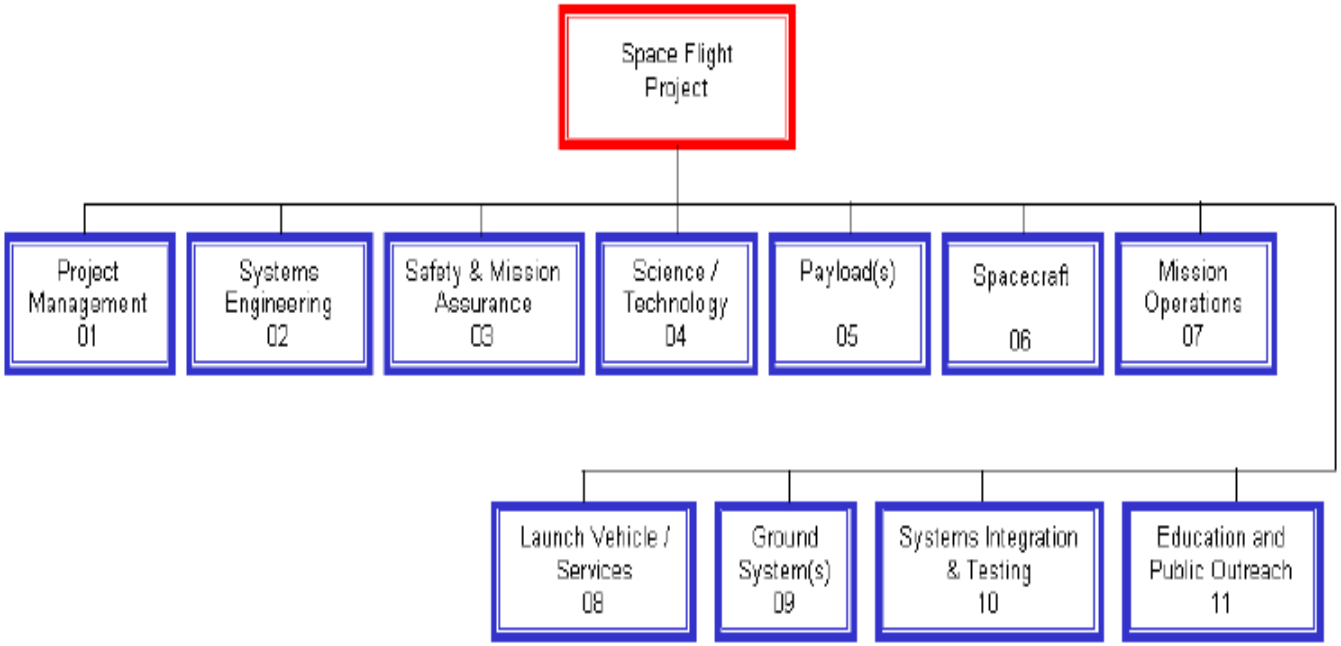
QuickCost 6.0 Database From ONCE/CADRe

SEER by GALORATH

1	EOM CADRe+	AIM (Aeronomy of Ice in the Mesosphere)
2	Post Launch CADRe	Aqua (Latin For Water) [formerly named PM-1 mission]
3	LRD	Aquarius
4	Post Launch CADRe Plus	AURA [formerly named CHEM or Chemistry mission]
5	EOM CADRe+	Cassini & Huygens Probe
6	CADRe Plus	CHIPSat (Cosmic Hot Interstellar Plasma Spectrometer Satellite)
7	Post Launch CADRe	CloudSat [dual launch with Calipso]
8	CADRe Plus	COBE (Cosmic Background Explorer)
9	LRD CADRe	DAWN
10	LRD CADRe	Deep Impact Flyby Spacecraft & Impactor
11	EOM CADRe	DS-1 (Deep Space 1)
12	Post Launch CADRe	EO-1 (Earth Observing 1)
13	CADRe Plus	FAST (Fast Auroral Snapshot Explorer)
14	LRD CADRe	GALEX (Galaxy Evolution Explorer)
15	CADRe Plus	Galileo Orbiter & Probe
16	CADRe Plus	Genesis (including sample return capsule)
17	EOM CADRe	GEOS I-M (Geostationary Operational Environmental Satellit
18	LRD CADRe	GLAST (Gamma Ray Large Area Space Telescope) [Renamed Fermi Gamma-ray Space Telescope]
19	LRD CADRe	GLORY
20	LRD CADRe	GPM (Global Precipitatino Measurement)
21	EOM CADRe	GRACE (Gravity Recovery and Climate Experiment) [Two Spacecraft but cost and cost drivers reflect one]
22	EOM CADRe	GRAIL (Gravity Recovery and Interior Laboratory)
23	LRD CADRe	IBEX (Interstellar Boundary Explorer)
24	CADRe Plus	ICESat (Ice, Clouds, and Land Elevation Satellite)
25	EOM CADRe	IMAGE (Imager for Magnetopause to Aurora Global Exploration)
26	LRD CADRe	IRIS (Interface Region Imaging Spectrograph)
27	CADRe Plus	JASON I
28	LRD CADRe	JUNO
29	LRD CADRe	KEPLER
30	LRD CADRe	LADEE (Lunar Atmosphere and Dust Environment Explorer)
31	EOM CADRe	LANDSAT-7
32	CADRe Plus	LCROSS (Lunar Crater Observatoin and Sensing Satellite)
33	LRD CADRe	LDCM (Landsat Data Coninuity Mission)
34	LRD CADRe	LRO (Lunar Reconnaissance Orbiter)
35	CADRe Plus	Mars Odyssey [Mars Surveyor 2001 Orbiter]
36	Non CADRe Sources	Mars Pathfinder
37	LRD CADRe	MAVEN (Mars Atmosphere and Volatile EvolutioN Mission)
38	CADRe Plus	MER (Mars Exploration Rover) Lander [Two Rovers but cost and cost drivers reflect one]
39	CADRe Plus	MGS (Mars Global Surveyor)
40	EOM CADRe	MRO (Mars Reconnaissance Orbiter)
41	LRD CADRe	MSL (Mars Science Laboratory) (Curiosity Rover)
42	CADRe Plus	NEAR (Near Earth Asteroid Rendezvous) [renamed NEAR Shoemaker]
43	LRD CADRe	New Horizons
44	LRD CADRe	NOAA-N
45	LRD CADRe	NOAA-N Prime
46	EOM CADRe	NUSTAR (Nuclear Spectroscopic Telescope Array)
47	LRD CADRe	OCO (Orbiting Carbon Observatory)
48	LRD CADRe	OCO 2 (Orbiting Carbon Observatory)
49	CADRe Plus	OSTM (Ocean Surface Topography Mission)
50	EOM CADRe	Phoenix
51	EOM CADRe	QuikSCAT
52	CADRe Plus	RHESSI (Reuven High Energy Solar Spectroscopic Imager)
53	CADRe Plus	SDO (Solar Dynamics Observatory)
54	CADRe Plus	SORCE (Solar Radiation and Climate Experiment)
55	EOM CADRe	Spitzer Space Telescope (formerly SIRTF-Space Infrared Telescope Facility)
56	EOM CADRe	Stardust & Sample Return Capsule
57	LRD CADRe	STEREO (Solar Terrestrial Relations Observatory) [2 observatories launched together]
58	LRD CADRe	Suomi NPP (Suomi National Polar-orbiting Partnership) (Previously known as the National Polar-orbiting Operational Environmental
59	CADRe Plus	SWAS (Submillimeter Wave Astronomy Satellite)
60	LRD CADRe	TDRS K/L (Tracking and Data Relay Satellite)
61	CADRE Plus	Terra (Latin for "Land") [Formerly named AM-1 mission]
62	LRD CADRe	THEMIS
63	CADRe Plus	TIMED (Thermosphere, Ionosphere, Mesosphere, Energetics and Dynamics mission)
64	CADRe Plus	TRACE (Transition Region and Coronal Explorer)
65	CADRe Plus	TRMM (Tropical Rain Measuring Mission)
66	LRD CADRe	Van Allen Probes (previously known as Radiation Belt Storm Probe (RBSP)
67	CADRe Plus	WIRE (Wide Field Infrared Explorer)
68	EOM CADRe	WISE (Wide-field Infrared Survey Explorer)
69	CADRe Plus	WMAP (Wilkinson Microwave Anisotropy Probe)

Cost Data Structure

- Cost fields in the updated database include the 11 cost elements contained in the NASA Standard WBS



QuickCost 6.0 Cost Output

- The major focus of the regression CERs and SERs in QuickCost 6.0 is being expended on WBS 5.0 (Spacecraft Bus) and WBS 6 (Payloads/Instruments)
  - The Spacecraft Bus will be estimated in total at the system level—no subsystem visibility)
  - Ditto each individual instrument
    - Based on several "instrument type" CERs/SERs
- The other 9 WBS elements will (probably) end up being cost to cost percentages (still a little TBD)

Variable Identification (1of 2)

- Starting point was the set of variables that have shown correlation with the cost and schedule of NASA missions in QuickCost 1.0 through 5.0…
  - Dry mass (kg)
  - BOL Power (watts) LEO Equivalent
  - Design life (months)
  - Destination (earth orbital, planetary)
  - ATP date (as a proxy for improvements over time in NASA productivity*)
  - Heritage (as Percent New Design)

- New variables being investigated…
  - Propellant load mass (kg)
  - RCS type (cold gas, mono-prop, bi-prop, dual mode)
  - Stabilization type (spinner/GG, 3 axis)
  - Array configuration (body mounted, deployed)
  - Array material (Si, GaAs)
  - Array areas (meters^2)
  - Battery type (NiCd, Super NiCd, NiH2, LiIon)
  - Battery capacity (amp-hours)
  - Thermal control (passive, active)
  - Data rate (kbps relative to ATP SOTA)
  - A number of others…..

"NASA Productivity", Joe Hamaker, Tom Coonce, Robert Bitten and Henry Hertzfeld, ICEAA Annual Workshop, June 2009, St. Louis

Variable Identification (2 of 2)

- Variables are being selected with the aid of standard statistical testing (t-tests) and good old common sense
  - Sensical algebraic signs on coefficients
  - Variables who cost driving logic can be explained in engineering terms
  - Variables that are "knowable" (excludes Chief Engineer's shoe size)
- And mainly quantitative variables
  - But Heritage or Percent New Design will still be an optional variable
- QuickCost 6.0 will provide the user with the capability of performing multiple estimates based on statistically acceptable CERs and SERs (see next chart)

Multiple Estimates

		Estimate Based On:					
Variable	Inputs	Mass Only	Mass & Power	Mass & Data Rate	Mass and Design Life	Mass, Power & Data Rate	Mass, Power, Data Rate & Design Life
Total Dry Mass (kg)	620.0	☑	☑	☑	☑	☑	☑
Total Power (watts)	700.0		☑			☑	☑
Data Rate (kbps)	20,000.0			☑		☑	☑
Design Life (months)	48				☑		☑
Resulting Cost Estimate		$242M	$259M	$251M	$263M	$248M	$256M
Resulting Scheudle Estimate		39 months	42 months	41 months	44 months	43 months	45 months

- Rather like the National Hurricane Center (NHC) using many models to predict the track and intensity of storms
- Different models use different variables and give different results

Regression Analysis and Model Structure

- Both Cost Estimating Relationships (CERs) and Schedule Estimating Relationships (SERs) are being developed

- Minitab is being used as the industrial strength regression package
  - Regression equation
  - Table of coefficients with SE, t and p statistics
  - S, R^2, R^2-adjusted
  - ANOVA table
  - Unusual observations
  - Etc.

JCL Technique Development

- QuickCost 6.0 will calculate both total cost and total schedule for proposed missions
- The model calculates the standard error of the estimate for both CERs and SERs
- And uses the SE to calculate prediction intervals around both cost and schedule estimates*
- The model will convolve these two probability distributions into a joint probability distribution (similar to NICM approach)
  - Thus the JCL will be based on the assumption that the scatter in the data encompasses all uncertainty (i.e. no probability ranges will be needed for input variables)

*Thanks to Andy Prince (NASA MSFC), Matt Pitlyk and Brian Alford (Booz Allen Hamilton) who provided the methodology for multivariable Prediction Intervals in the March 2015 "Ask A Cost Analyst" column of *ICEAA World*

Summary

- QuickCost 6.0 will provide updated and enhanced capabilities for straight-forward and transparent estimation of proposed NASA missions based on validated historical databases

- Remember….coming to you December 31, 2015 (midnight)